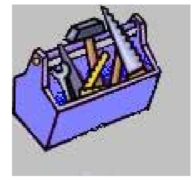
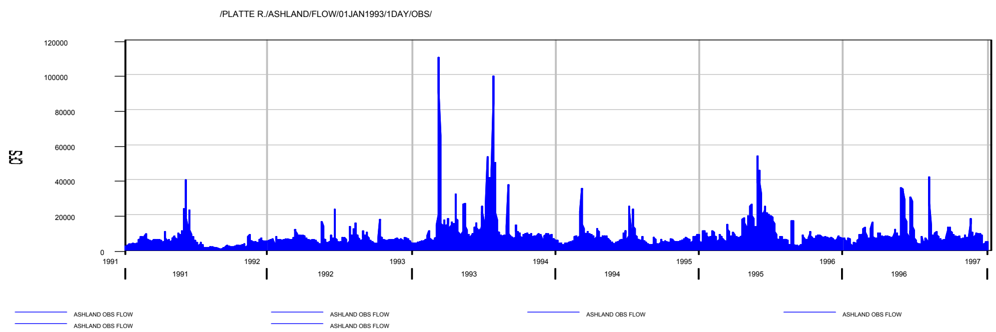
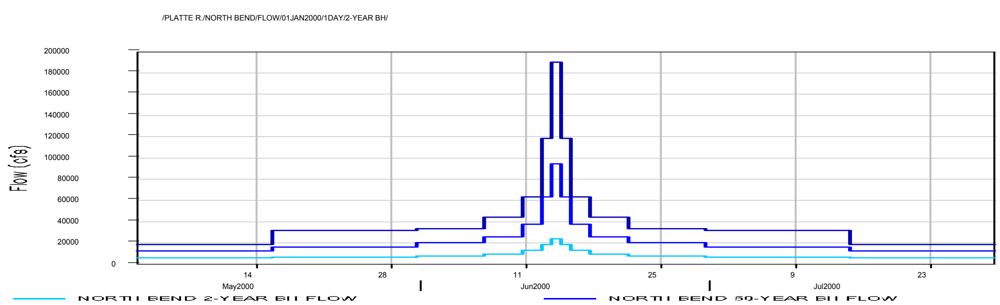
OTHA – Omaha Tools for Hydrologic Analysis

Time-Series/Statistical Analysis Programs for Water Resources



User's Manual





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US Army Corps of Engineers®
Omaha District

Overview

A suite of programs has been developed by the Omaha District to provide useful tools to aid in the rapid and accurate analysis of hydrologic daily flow time-series data and peak flow data for various water resources/environmental projects. These programs utilize tools not currently found in existing software and all the OTHA programs have: easy-to-use Visual Basic GUI interfaces, FORTRAN engines, connections to WEB data locations, data conversion utilities, and utilize standard data formats: HEC-DSS databases for daily flows and HEC-FFA input formats for instantaneous peak flows. Various water resources related routines within OTHA include: time-series cross-correlation analysis, trend analysis, volume-frequency/balanced-hydrograph generation, extension of records, synthetic peak flow generation, mix-population analysis, total probability theorem analysis, risk/binomial distribution analysis, precipitation-frequency analysis using General Extreme Value 1 distribution, and tests for stationarity or linear trends of statistical parameters.

Model Development. The programs contained in OTHA are predominantly software that had been previously developed by the Omaha District Corps of Engineers in the course of analyzing various water resources projects. The primary purpose of OTHA was to compile all the existing programs into one easy-to-use package and to be able to use these programs in conjunction with traditional statistical analysis software such as HEC-FFA and HEC-STATS. Specific model goals include:

1. Provide direct access to data via the Internet.
2. Provide means to convert data into a standardized format (DSS for daily data and HEC-FFA input file format for instantaneous peak flow data).
3. Minimize amount of required data input.
4. Direct display of program output.
5. Provide for annual or seasonal analysis when using daily values.
6. Provide a common “look or feel” for all routines.
7. Provide useful set of tools for working engineers.

Model Use. All routines within OTHA were written with FORTRAN and have a Visual Basic graphical user interface. The routines within OTHA are called from a main menu or screen and are located within one of four main folders:

1. Daily Flow Programs
   - *DAILYDSS*
   - *DSSSTATS*
   - *CORRDSS*
   - *BALHYD*
   - *DSSDIFF*
2. Instantaneous Peak Flow Programs
   - *QWAT*
   - *EXTENSION*
   - *QGEN*
   - *MIXPOPS*
   - *TOTPROB*
   - *STATIONARITY*

3. Precipitation and Risk Programs
   - *PRECFREQ*
   - *RISK*
   - *MEANPEAK*

4. Links to HEC Programs
   - *DSPLAY*
   - *DSSUTL*
   - *DSSVUE*

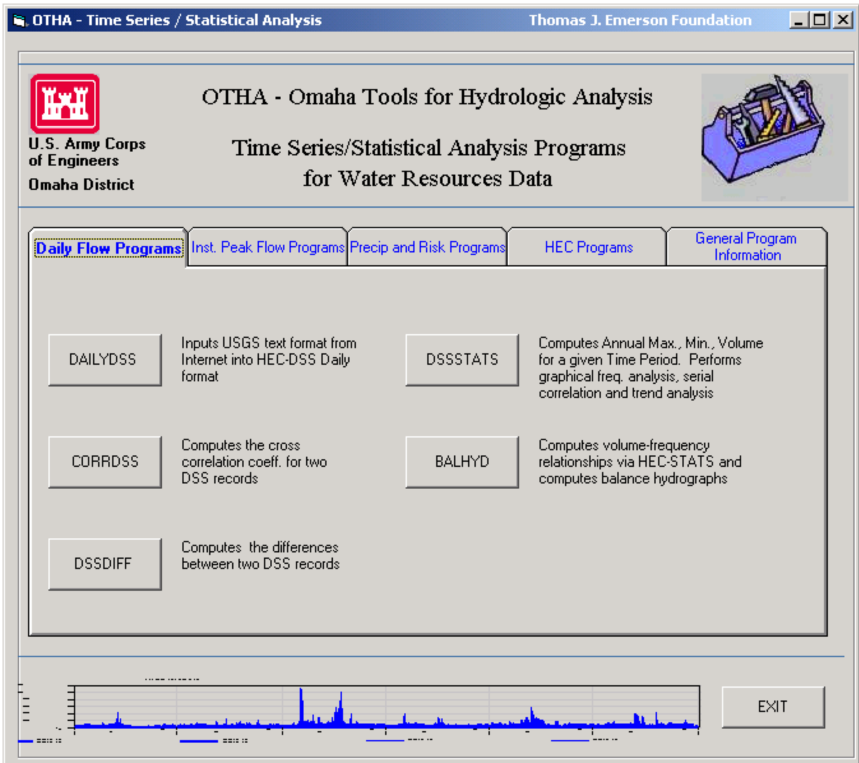
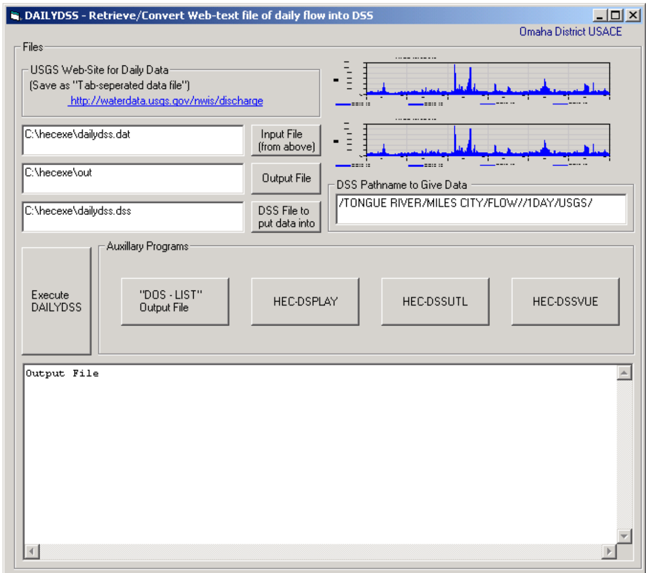


Figure 1. OTHA Main Menu

The graphical user interface for each routine is shown below along with a brief description of each routine. For detailed descriptions of all routines, please refer to the OTHA Users Manual, which can be found at:

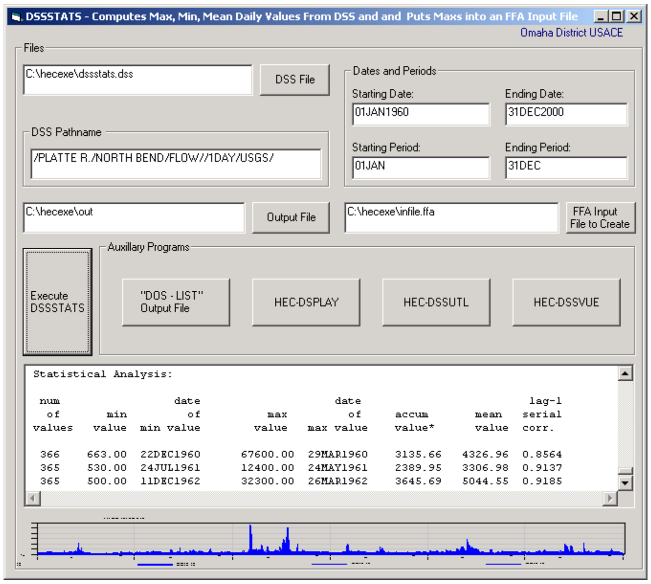
http://www.nwo.usace.army/OTHA

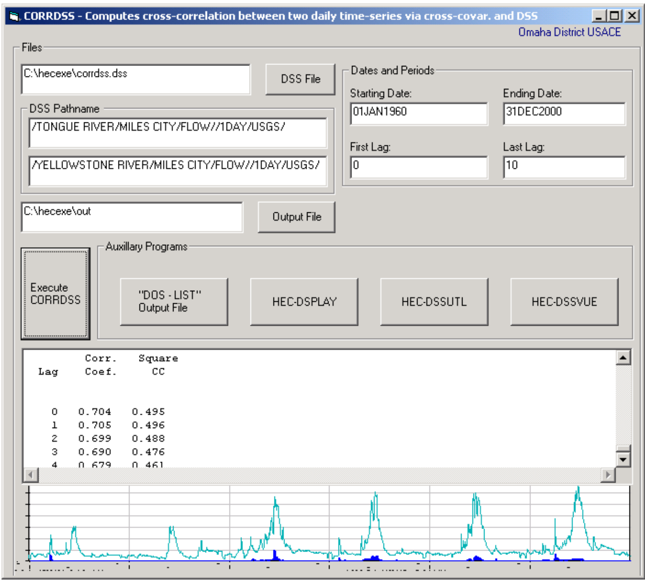
Daily Flow Routines:



DAILYDSS – Retrieves daily flow data from USGS Web-Site and converts the data into HEC-DSS daily time-series. The data from the Web Site needs to be saved as a “Tab-Separated Data File”. The name of the DSS file needs to be inputted, as well as the DSS pathname for the data to be placed in are required input.

DSSSTATS – Quickly and concisely summarizes a long-term period of record of daily flows for any period within a year into: annual minimum flows, annual maximum flows, annual mean flows, annual flow-volumes, annual lag-1 serial or autocorrelation coefficients, and computes graphical frequency-analysis, log-Pearson probability distribution, and trend analysis on annual maximum daily flow values with associated statistical significance tests. Writes out annual maximum flows to an FFA input file for further analysis.





CORRDSS- Calculates the cross-correlation of two hydrologic daily time-series using the cross-covariance between the two hydrologic time-series. (Salas, 1992) Essentially, determines the probability that two rivers will flood at the same time – useful for main/tributary confluences and interior drainage analysis.

$$r_k^{ij} = \frac{c_k^{ij}}{(c_o^{ii} c_o^{jj})^{1/2}}$$

$$c_k^{ij} = \left(\frac{1}{N}\right)\sum_{i=1}^{N-k} (y_{t+k}^{i} - y_{mean}^{i})(y_{t}^{j} - y_{mean}^{j})$$

where:

y^i = one stream gage's time-series of daily flows

y^j = another stream gage's time-series of daily flows

c_o= sum of the differences of daily flows from the mean of the daily flows, divided by the total number of observations

t = time increment

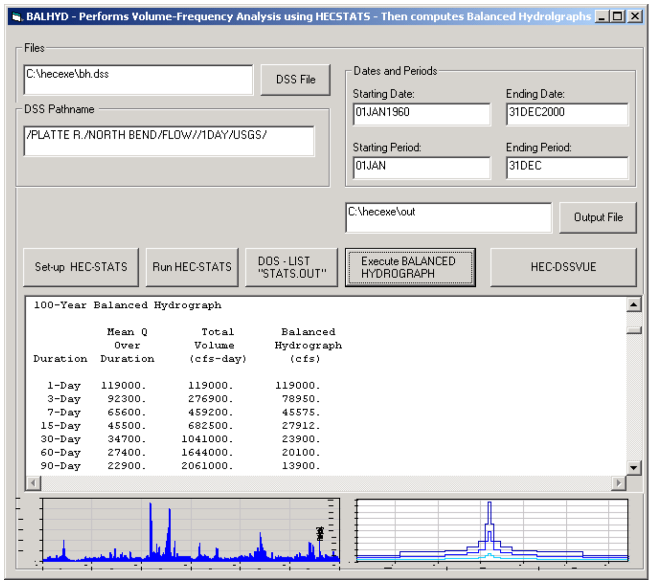
r_k = lag-k cross-correlation coefficient

c=cross-covariance between the two time-series

k=times-series lag

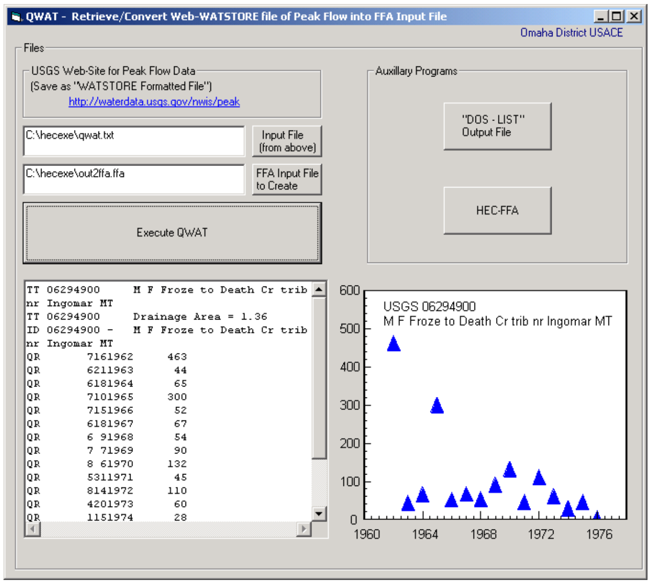
N=total number of values

BALHYD – Serves as a graphical interface for HEC-STATS for flow volume-frequency analysis, then computes various return-interval symmetrical hypothetical "balanced" hydrographs and writes the ordinates out to HEC-DSS. Specific periods within the year can be computed, i.e. monthly or seasonal. The generated balanced 10, 25, 50, 100, and 500-year hydrographs are written to the specified DSS file.



The program writes out the balanced hydrographs back to the DSS file listed in the GUI using the original pathnames, except for the F-part which is fixed as "2-Year BH", "5-Year BH", etc.

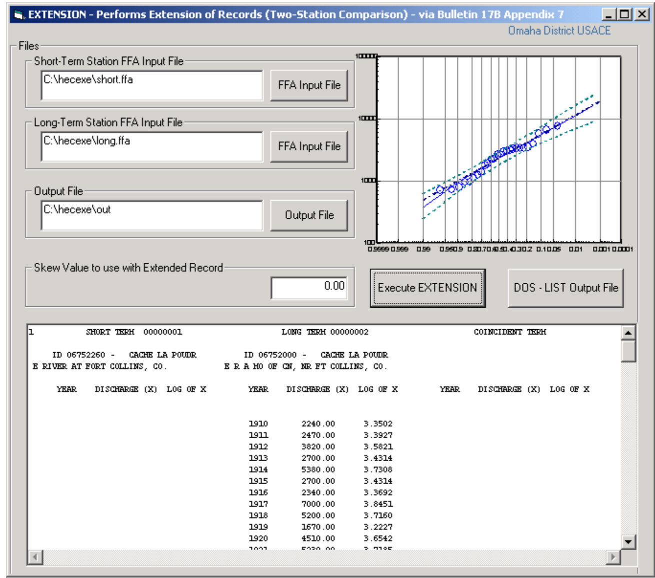
The duration of the balanced hydrograph is limited to 90-days.

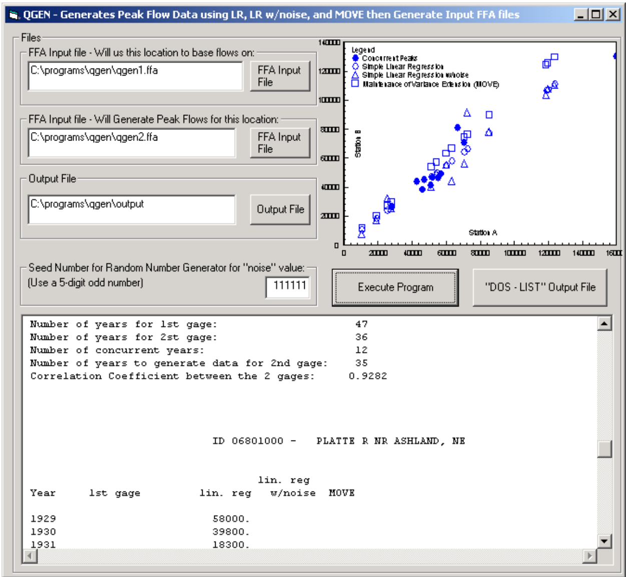


Peak-Flow Routines:

QWAT – Retrieves and converts USGS WATSTORE file format from the USGS's Web Site into an HEC-FFA input file format (QR Cards).

EXTENSION - Extension of records or two-station comparison of peak flows. Utilizes the procedures described in Appendix 7 of Bulletin 17B for extending on gage's record based on the concurrent period of a nearby gage. The program adjusts the log mean flow and standard deviation of the short-term record based on the regression analysis with the long-term record. An inputted skew value can be used with the adjusted parameters to develop the final flow-frequency curve. (Hydrology Subcommittee, 1982)





QGEN - Will generate individual year's peak flows for a given station by comparison with nearby station. Will generate missing year flows by linear regression, linear regression with "noise", and MOVE statistics. (Salas, 1991) The program puts the original data combined with the synthetic data into three FFA input files.

$$y_t = a + b(x_t - \mu_t)$$

$$a = \frac{(N_1 + N_2)\mu_y - N_1\mu_{y1}}{N_2}$$

$$\mu_y = \mu_{Y1} + \frac{N_2}{N_1 + N_2}\rho_{xy}\frac{\sigma_{Y1}}{\sigma_{X1}}(\mu_{X2} - \mu_{X1})$$

$$b^2 = \frac{[(N_1 + N_2 - 1)\sigma_y^2 - (N_1 - 1)\sigma_{Y1}^2 - N_1(\mu_{Y1} - \mu_y)^2 - N_2(a - \mu_y)^2]}{(N_2 - 1)\sigma_{X2}^2}$$

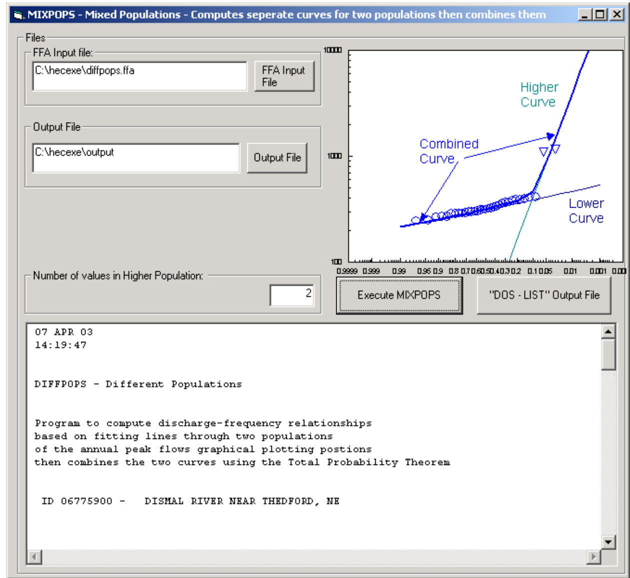
$$\sigma_y^2 = \frac{1}{N_1 + N_2 - 1}[(N_1 - 1)\sigma_{Y1}^2 + (N_2 - 1)\rho_{xy}^2\frac{\sigma_{Y1}^2}{\sigma_{X1}^2}\sigma_{X2}^2 + \frac{N_1 N_2}{N_1 + N_2}\rho_{xy}^2\frac{\sigma_{Y1}^2}{\sigma_{X1}^2}(\mu_{X2} - \mu_{X1})^2$$

$$+ (N_2 - 1)\alpha^2(1 - \rho_{xy}^2)\sigma_{Y1}^2]$$

X is the set of annual peak flows for the long-term gage
Y is the set of annual peak flows for the short-term gage
μ_y and σ_y are the mean and standard deviation of the extended sequence
y_t is the variable with a missing variable to be generated
μ_{y1} is the mean of concurrent observations of Y
ρ_{xy} is the cross-correlation between X and Y
σ_{y1} is standard deviation of concurrent observations of Y
σ_{x1} is standard deviation of concurrent observations of X
σ_{x2} is standard deviation of non-concurrent observations of X
x_t is the variable with the complete record
μ_{x1} is the mean of concurrent observation of X
μ_{x2} is the mean of non-concurrent observation of X
N_1 is the number of common observations between X and Y
N_2 is the number of values of Y to generate and:

$$\alpha^2 = \frac{N_2(N_1 - 4)(N_1 - 1)}{(N_2 - 1)(N_1 - 3)(N_1 - 2)}$$

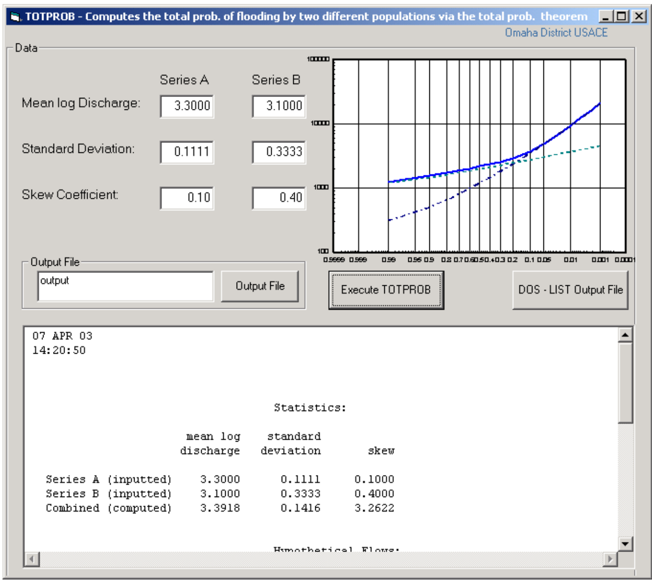
MIXPOPS - For two physically-differentiated populations within one FFA record, the program will compute separate flow-frequency curves for each population then combines the two curves using the Total Probability Theorem. The curves are developed by converting the graphical plotting positions to a linear distance on the probability grid and solves for a best-fit line. (HEC, 1975)



$$P_{Combined} = P_A + P_B - P_A P_B$$

where:
P_A *= Probability of "A" occurring*
P_B *= Probability of "B" occurring*

The number of values in the Higher Curve needs to be inputted in the GUI. The program performs an initial graphical frequency analysis to detect the upper points. For the upper curve, the program also takes the highest point on the Lower Curve to develop the best-fit line. For the combined-curve the program determines the combined probability at each cfs flow increment and then interpolates the 2-,5-,10-,25-,50-,100-,200-, and 500-year combined values.



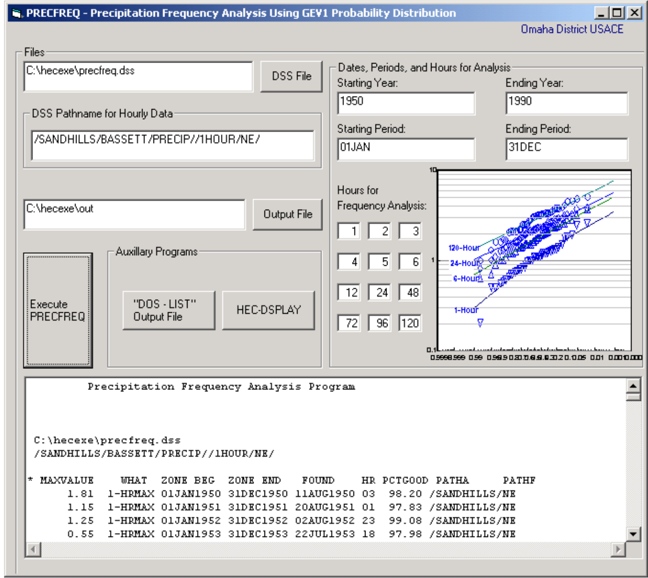
TOTPROB - Given the statistical parameters of mean log discharge, standard deviation, and skew for two different populations, the program will compute the log-Pearson Type III probability distribution for each, then combine the two curves for a smooth curve using the Total Probability Theorem.

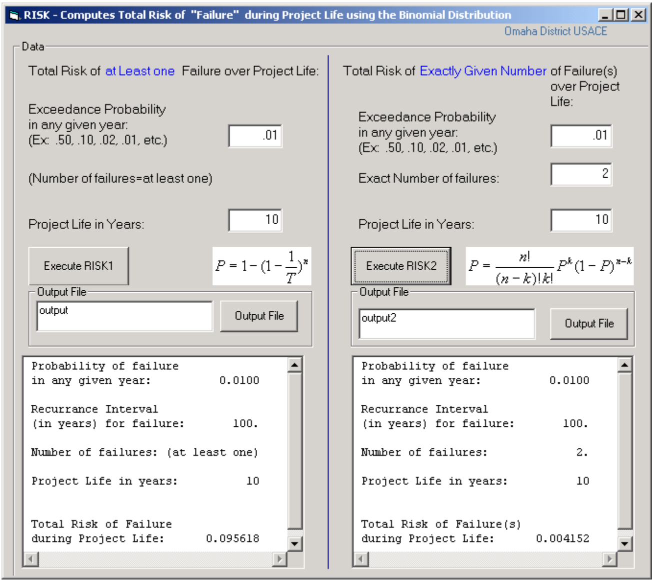
$$P_{Combined} = P_A + P_B - P_A P_B$$

Ten-thousand points are determined for each series of frequency curves, then the program determines the combined probability at each cfs flow increment and then interpolates the 2-,5-,10-, 25-,50-,100-,200-, and 500-year combined values.

Precipitation and Risk Routines:

PRECFREQ - Precipitation-frequency analysis of hourly precipitation data using the General Extreme Value 1 probability distribution. The program sorts the hourly DSS records to determine the max "n-hour" for each year then computes graphical frequency analysis using the Weibull plotting positions as well as the GEV-1 analytical solution. Specific periods within the year can be computed, i.e. monthly or seasonal.





RISK - Computes the total risk of failure over a project life using the Binomial Probability Distribution (Chow, Maidment, Mays, 1988) based on the following equations:

$$R = 1 - (1 - \frac{1}{T})^n$$

$$R = \frac{n!}{(n-k)!k!} P^k (1-P)^{n-k}$$

where:

R = Risk of occurance

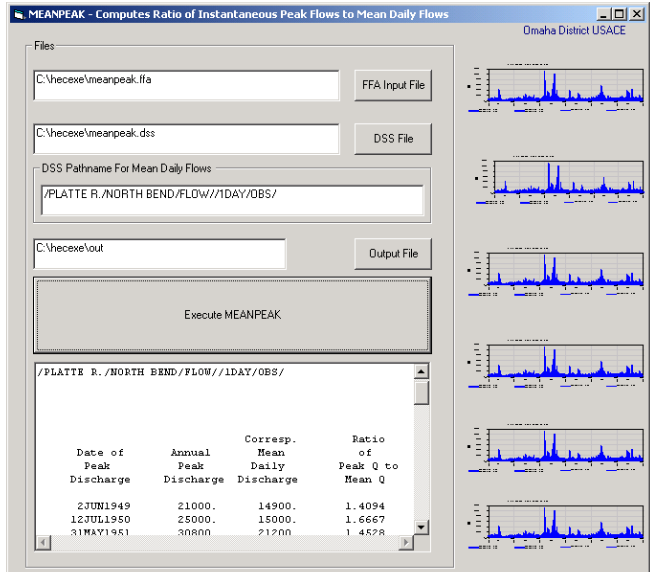
P = Probability in any year

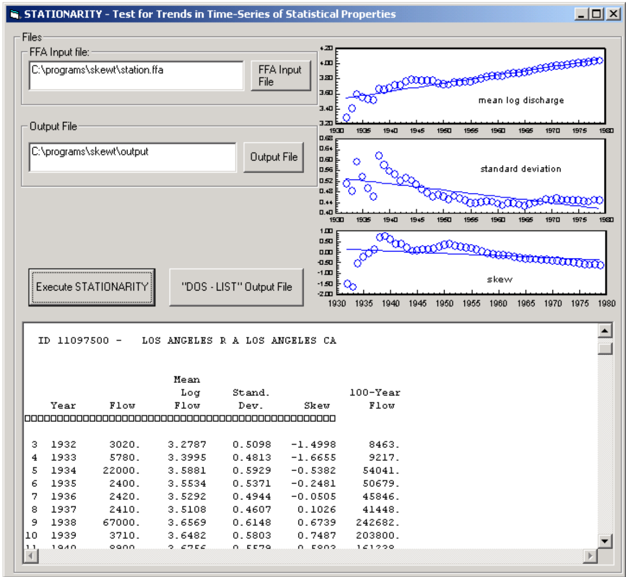
T = Recurrance interval

K = Number of floods

N = Number of years

MEANPEAK - Computes the ratio of mean daily flows to instantaneous peak flows given a FFA input file and mean daily flow DSS file. The programs takes the peak flow from the FFA input file for each year, then searches the mean daily flow DSS file to determine the corresponding mean daily flow for the day the instaneous peak flow occurred and computes the ratio. The program also determines the mean ratio between peak flows and mean daily flow for all years.





STATIONARITY - Computes time-series of statistical properties of mean log discharge, standard deviation, skews, as well as the analytically-based 100-year flow as a test for basin stationarity. Allows to see how the 100-year flow estimate changes with time and to readily see which statistical parameters influenced the changes. Performs trend-analysis on statistical parameters and tests the statistical significance of the trends using the Students t-test:

Test Statistic:

$$T_c = \frac{b\sigma_x\sqrt{N-1}}{\sigma_\varepsilon}$$

b = *slope of regression curve*

σ_x = *standard deviation of parameter*

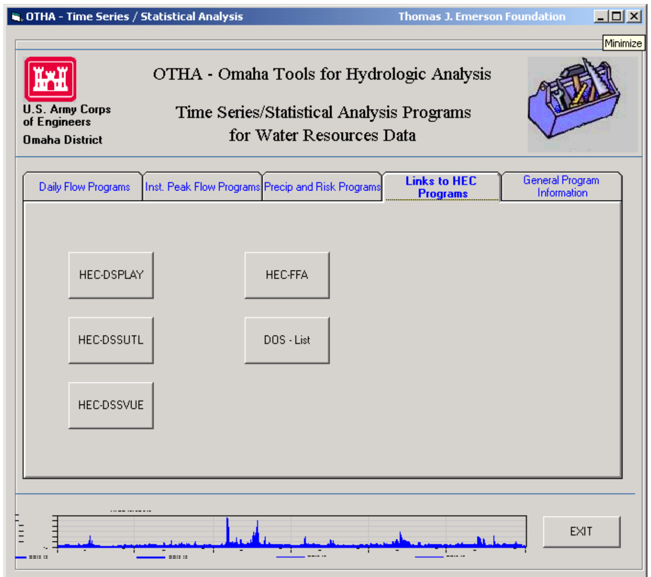
σ_ε = *standard deviation of residuals between actual values and regression values*

N = *number of values*

Hypothesis test: b=0 is rejected if: $|T_c| \rangle T_{1-\alpha/2}(N-2)$ where α is the significance level.

HEC Program Links:

A folder was created within OTHA to allow easy access to existing HEC programs. OTHA will make the links to the files if they are already loaded on the PC.



References

Chow, Maidment, Mays (1988). *Applied Hydrology*.

HEC (1975). *Hydrologic Engineering Methods for Water Resources Development, Volume 3 Hydrologic Frequency Analysis.*

Hydrology Subcommittee (1982). *Bulletin #17B – Guidelines For Determining Flood Flow Frequency.*

Salas, Jose D. (1991). *Statistical Computer Techniques in Hydrology and Water Resources.*

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